Reducing Computational Time of Closed-Loop Weather Monitoring:

A Complex Event Processing & Machine Learning Based Approach

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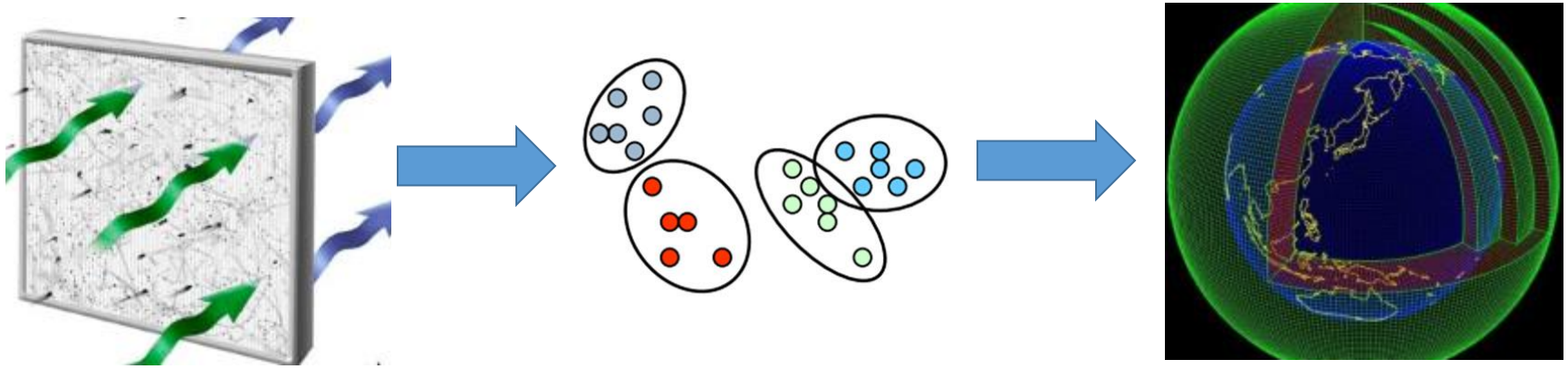
[*]WSO2 Inc., Sri Lanka

Contribution

We attempt to address drawbacks of current weather forecasting approaches by pre-processing weather data using Complex Event Processing and Machine Learning



CEP based filter

ML based clustering module

Complex, weather processing module

Introduction

Weather forecasts…

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ENHANCED WEATHER MONITORING SYSTEM

Very important and need to be **timely** and **accurate**

But weather algorithms have to process **too much data**

The Real Problem

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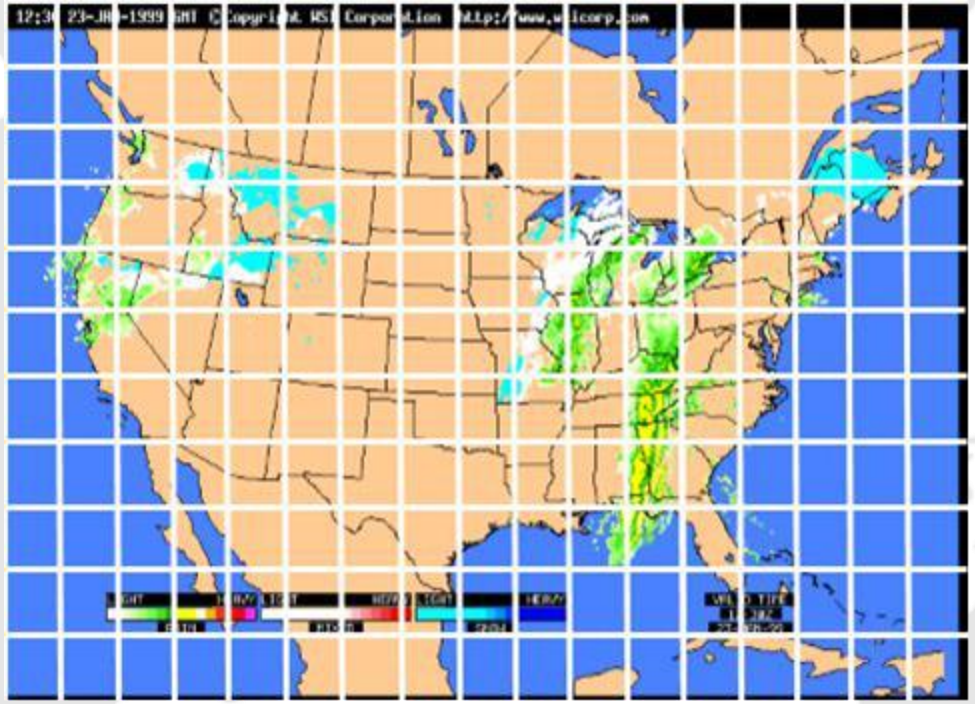
Data collection is,

- **Static**
- **Fixed-Cycle**
- **Low Resolution**



The Answer!

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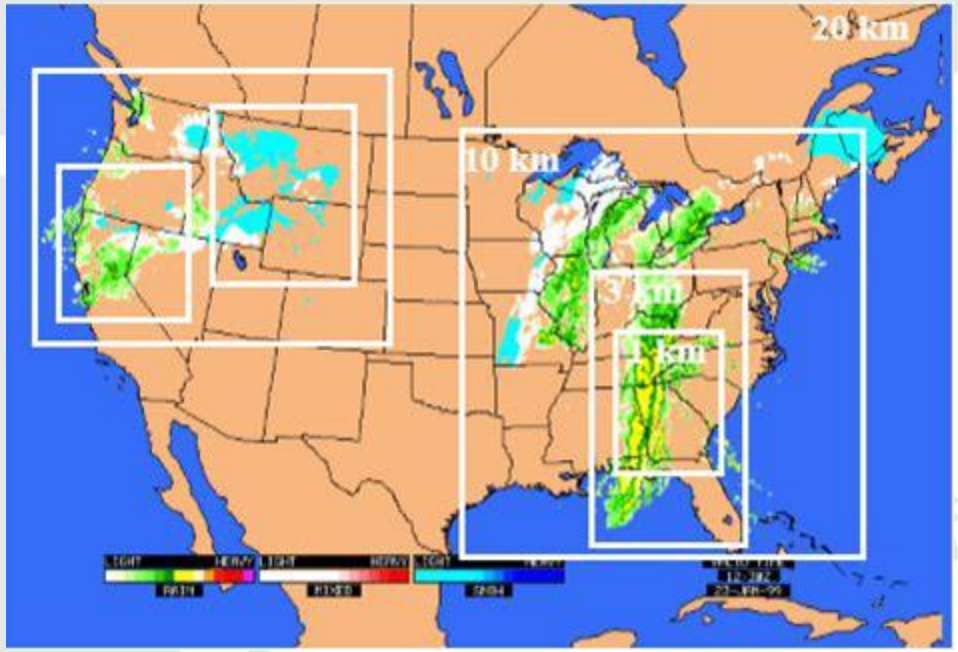
- Identifying interesting areas if any
- Increasing the data collection resolution
- Increasing the data collection frequency



Solution Architecture

High Level Solution…

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2 Solution Architecture

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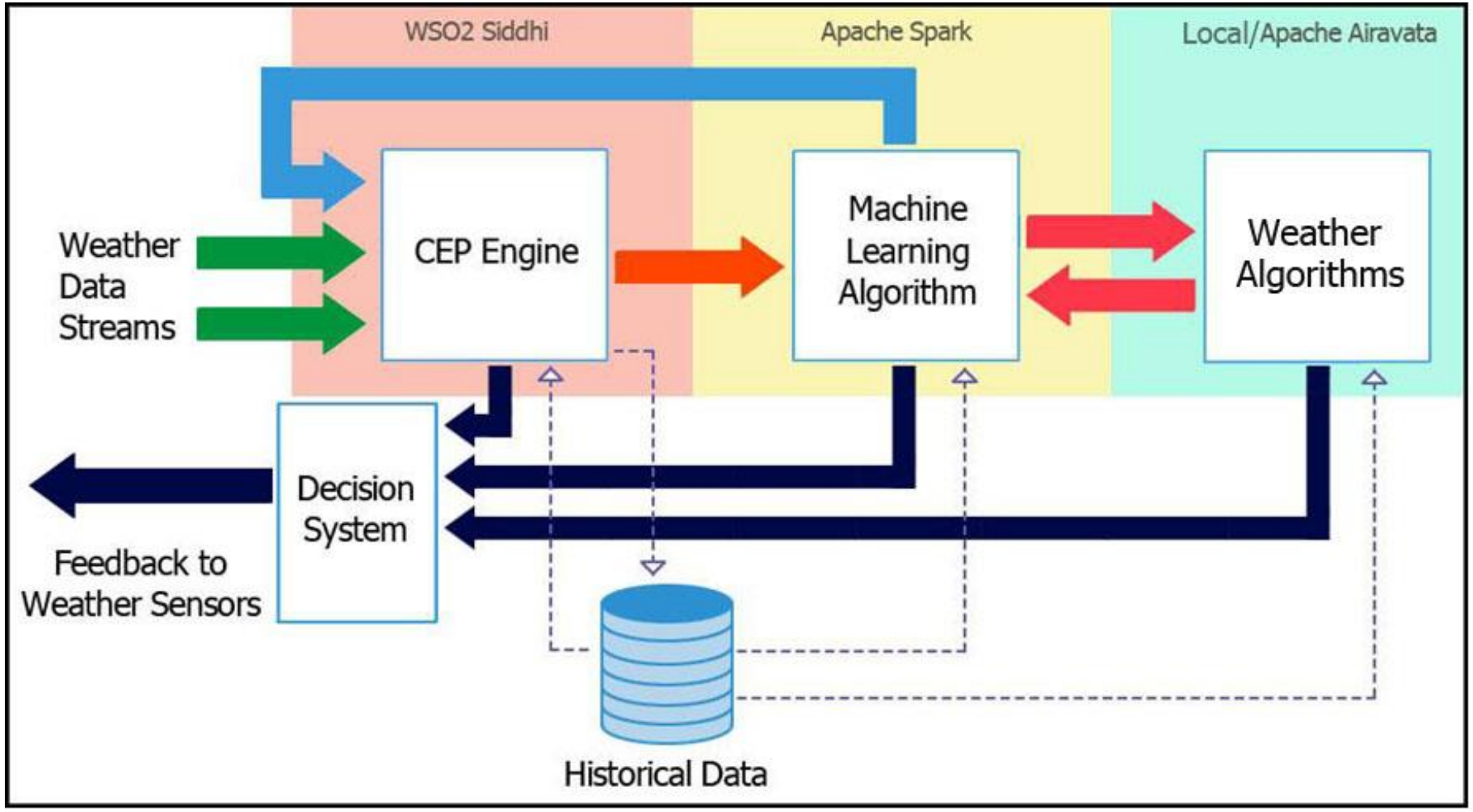

Selected Case

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2 Solution Architecture
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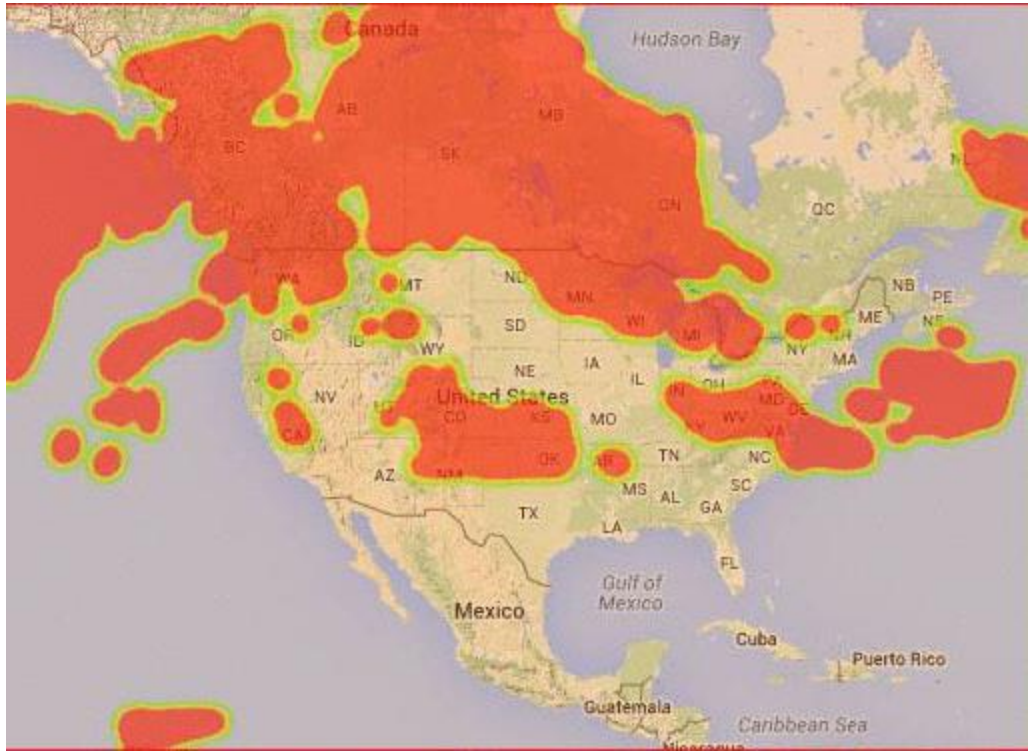
2006 December, 19-20

Decatur, United States

3 -Hourly Data in GRIB* format



* GRIB is a data format dedicated to handle weather data

Initial Data Coverage

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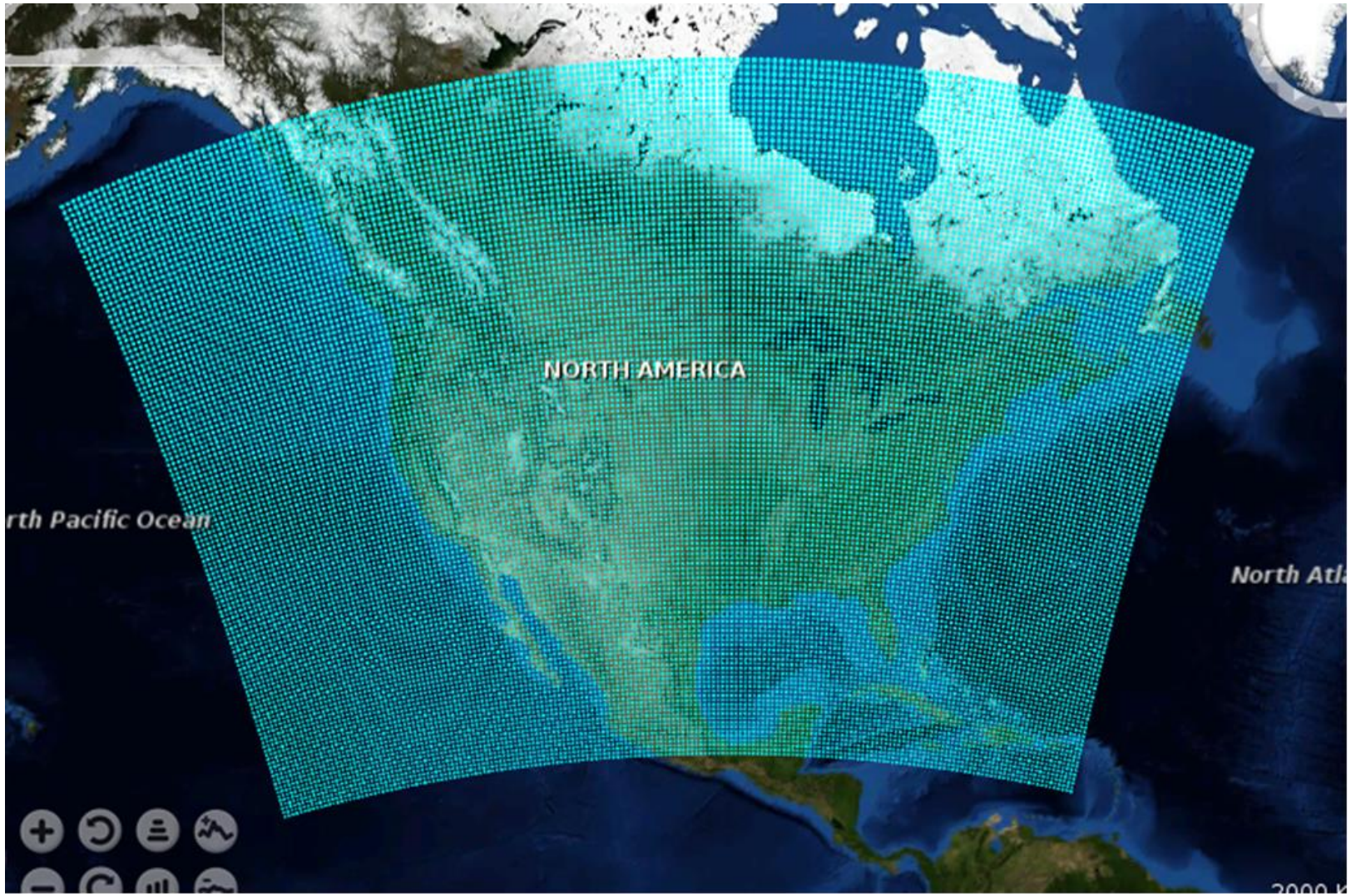

High Level Solution…

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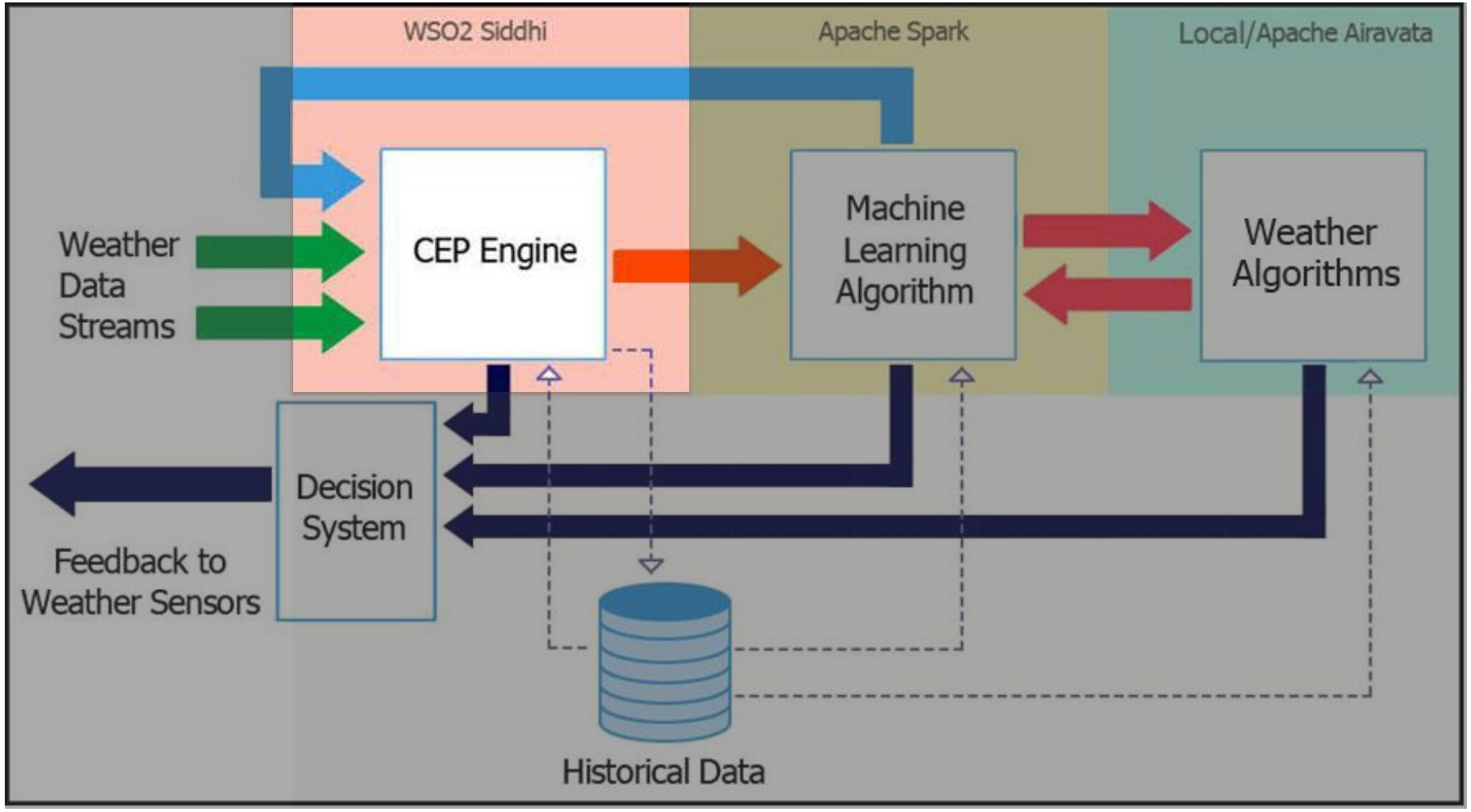

CEP Filtering Layer

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Complex Event Processing

- Monitoring data streams in real time
- Identifying complex relationships among events (data)
- We used it to monitor weather stream data

Goals

- Anomaly detection
- Filtering

Filtering using weather indices

- Lifted Index
- Storm Relative Helicity
- Convective Inhibition

Lifted Index

LI ≥ 0K : *Stable atmosphere - no thunderstorms possible*
0K > LI ≥ −2K : *Thunderstorms possible*
−2K > LI ≥ −6K : *Thunderstorms likely*
−6K > LI : *Severe thunderstorms likely*

CEP Filtered Data

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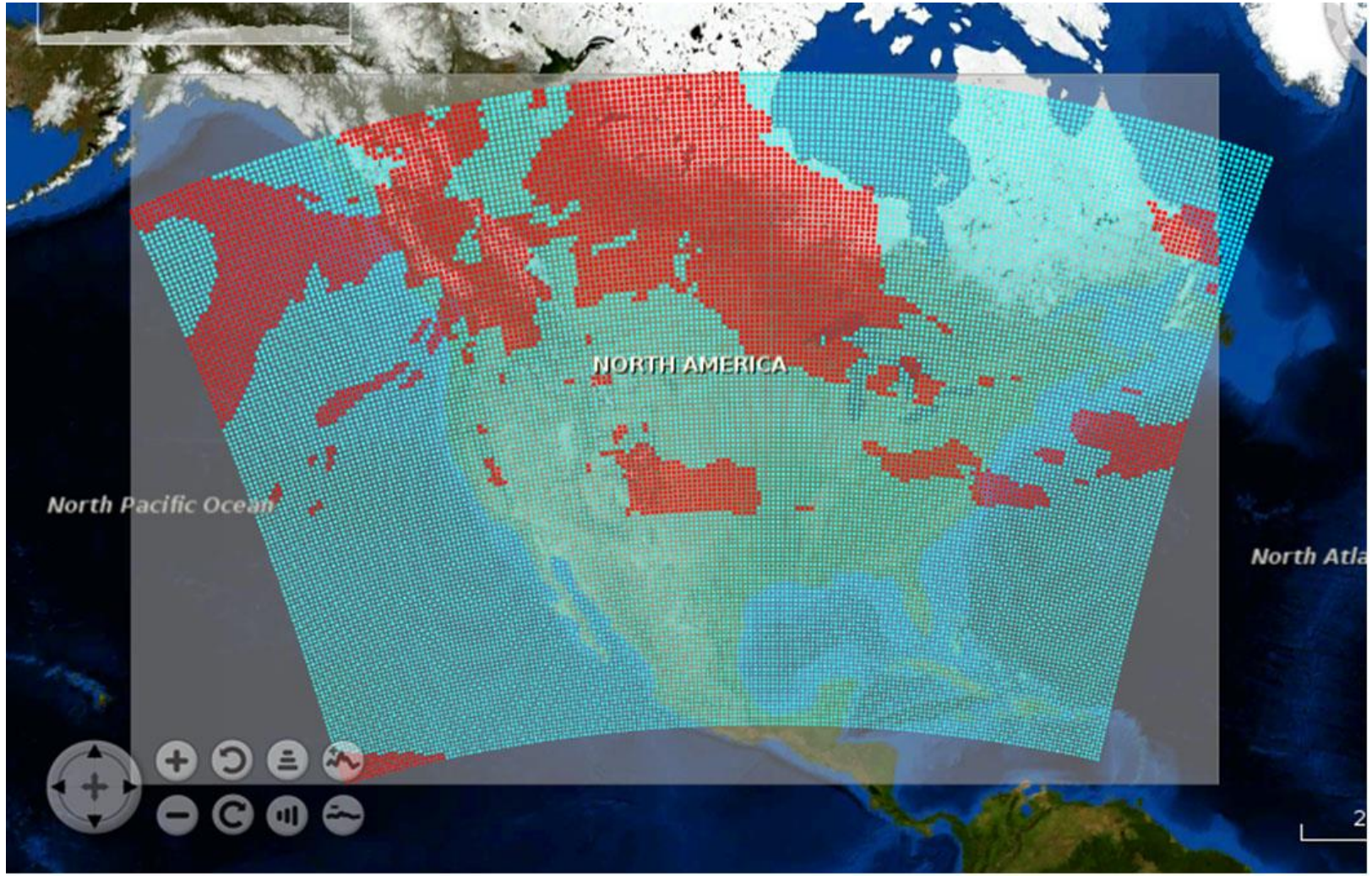

High level solution…

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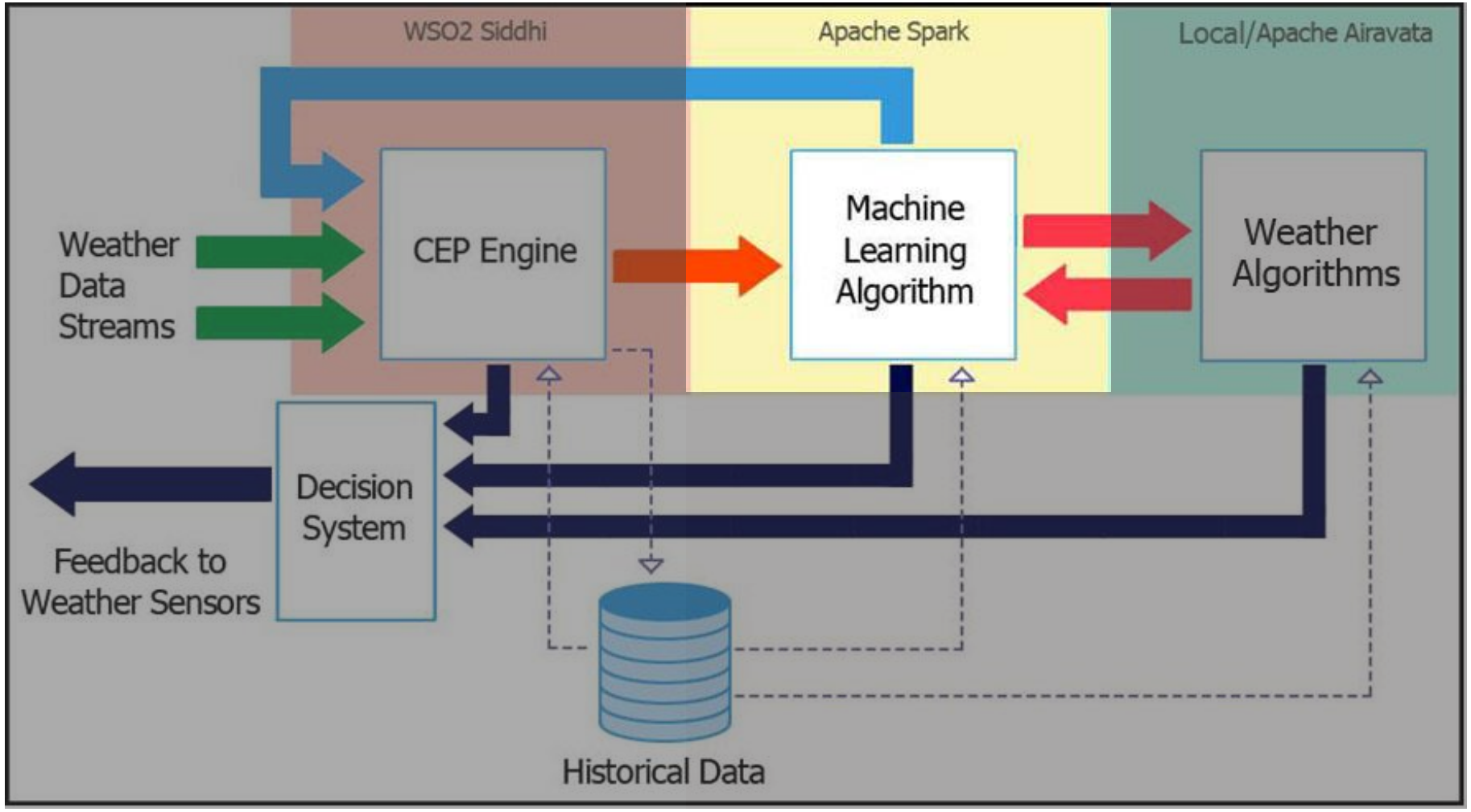

ML Clustering Layer

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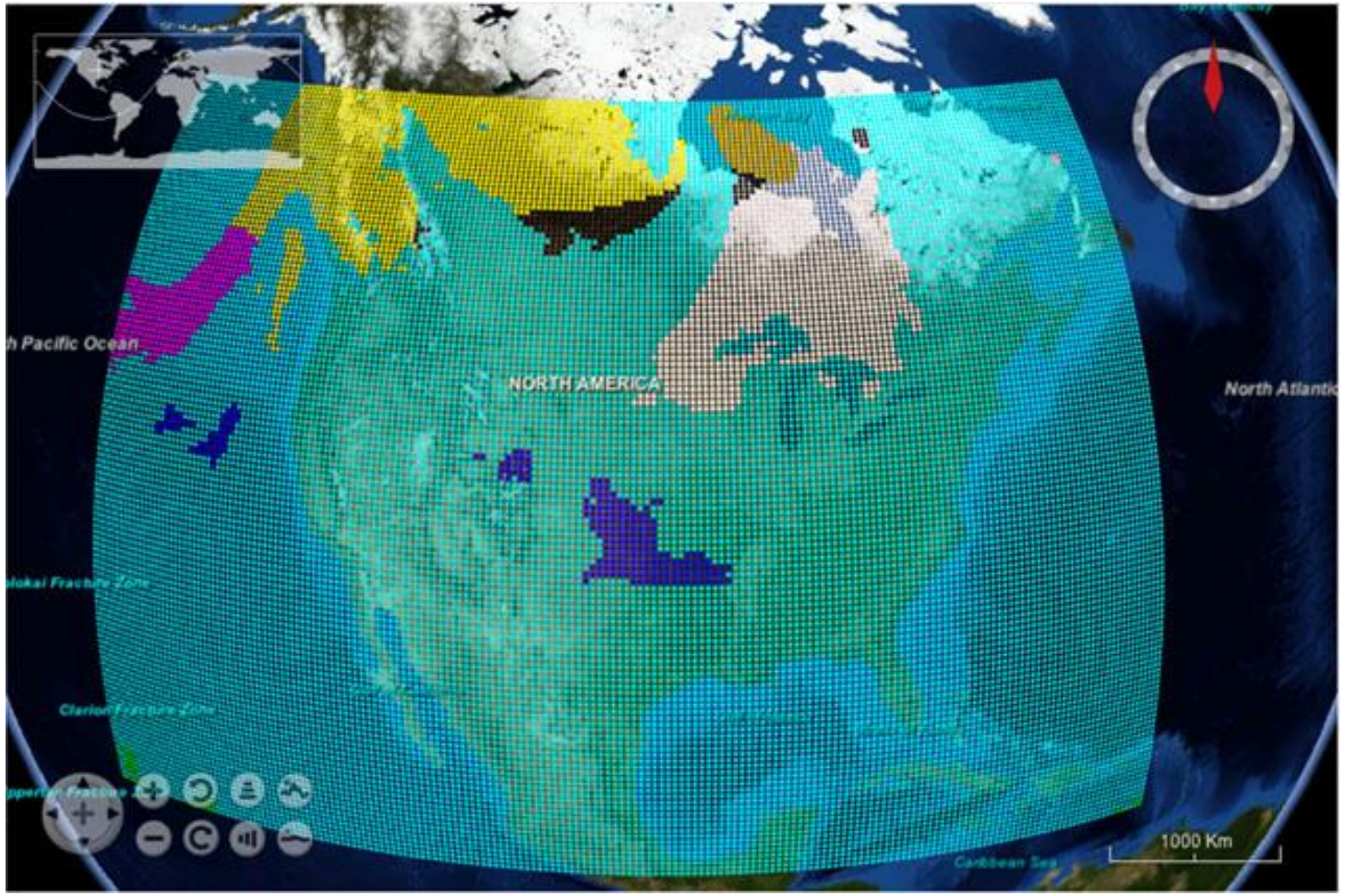
Used to

- Cluster the data points
- Get localized boundaries

2 Algorithms used

- K-means
- Gaussian Mixture Model

Apache Spark



K-Means Results

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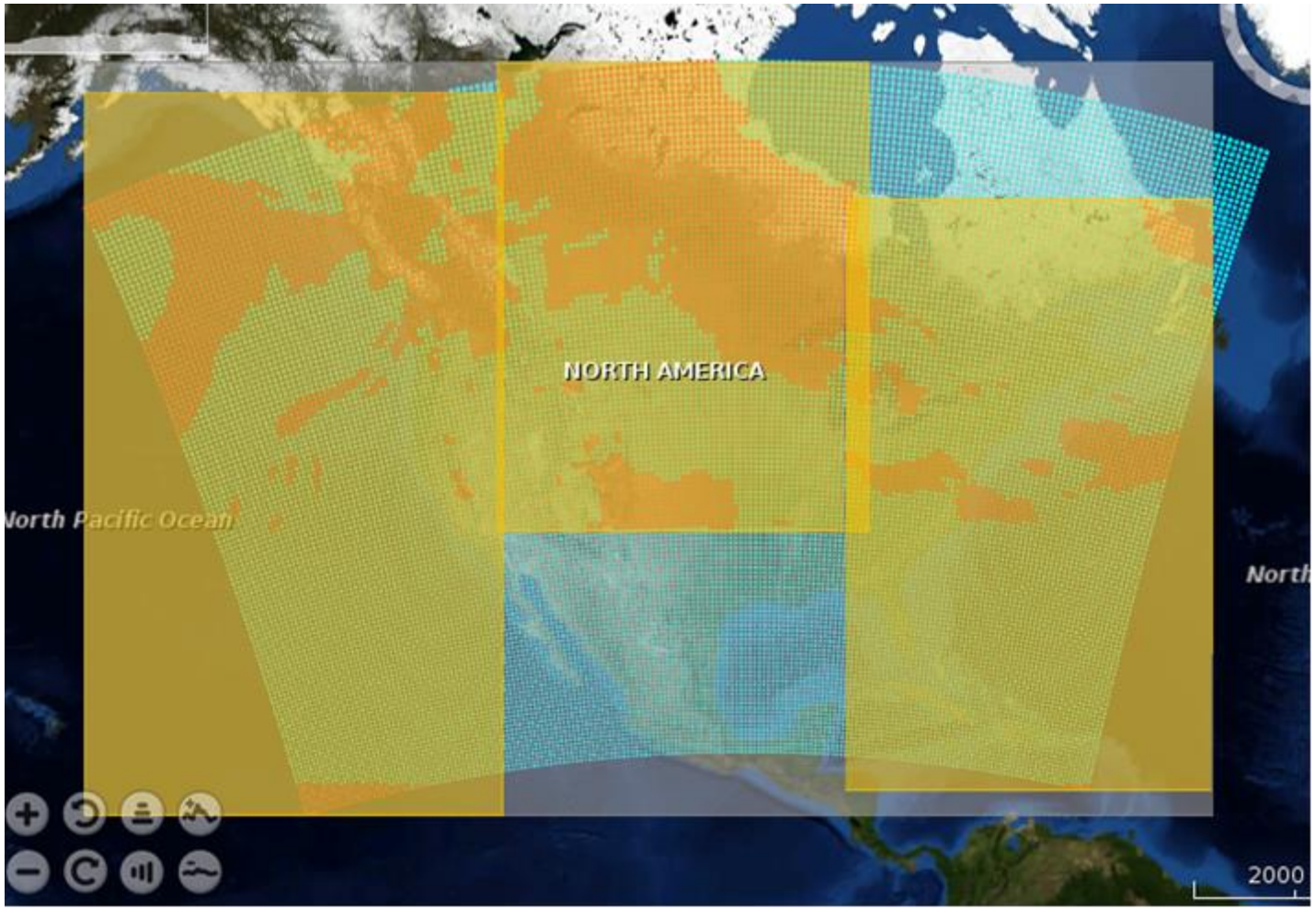

GMM Results

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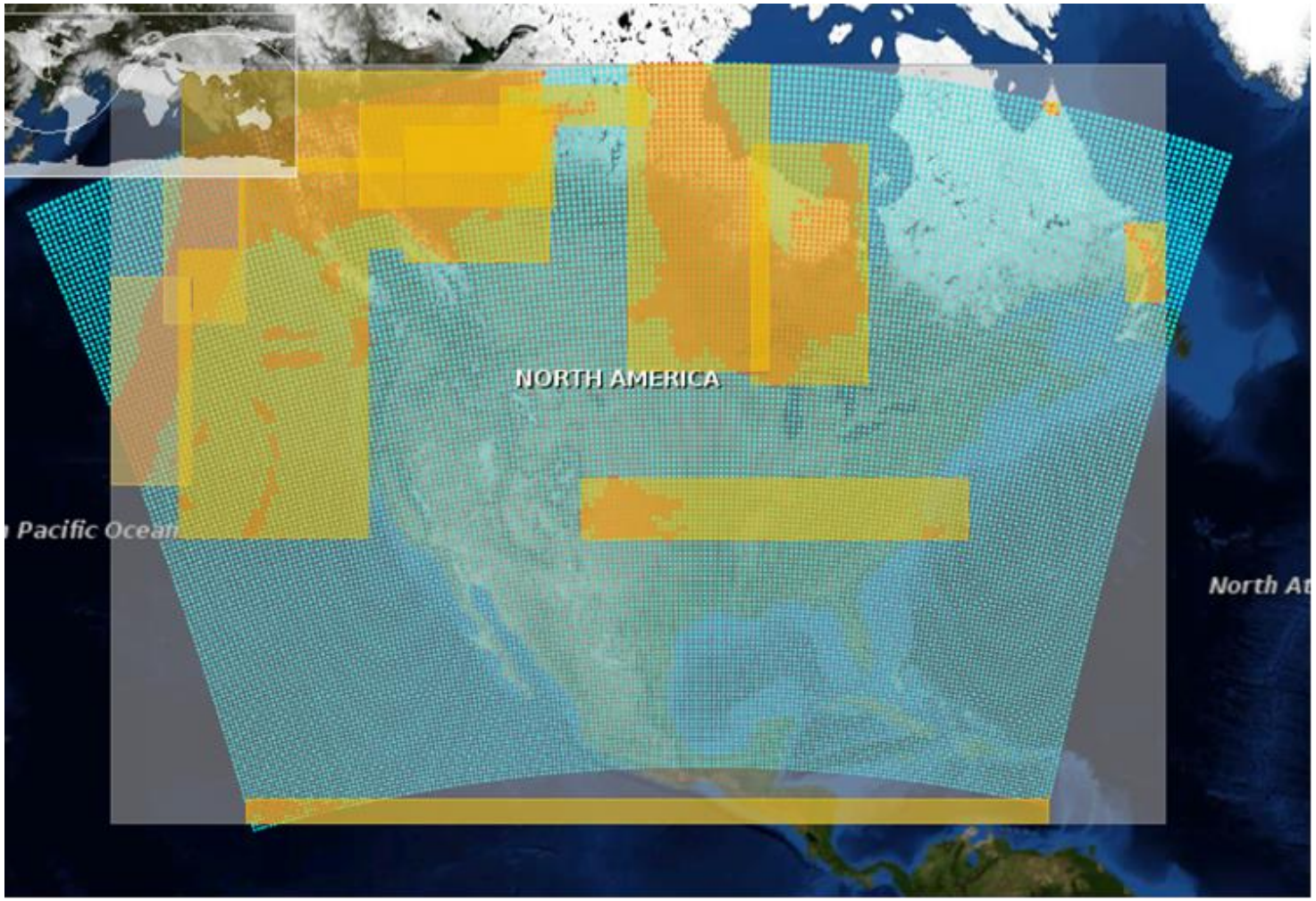

High level solution…

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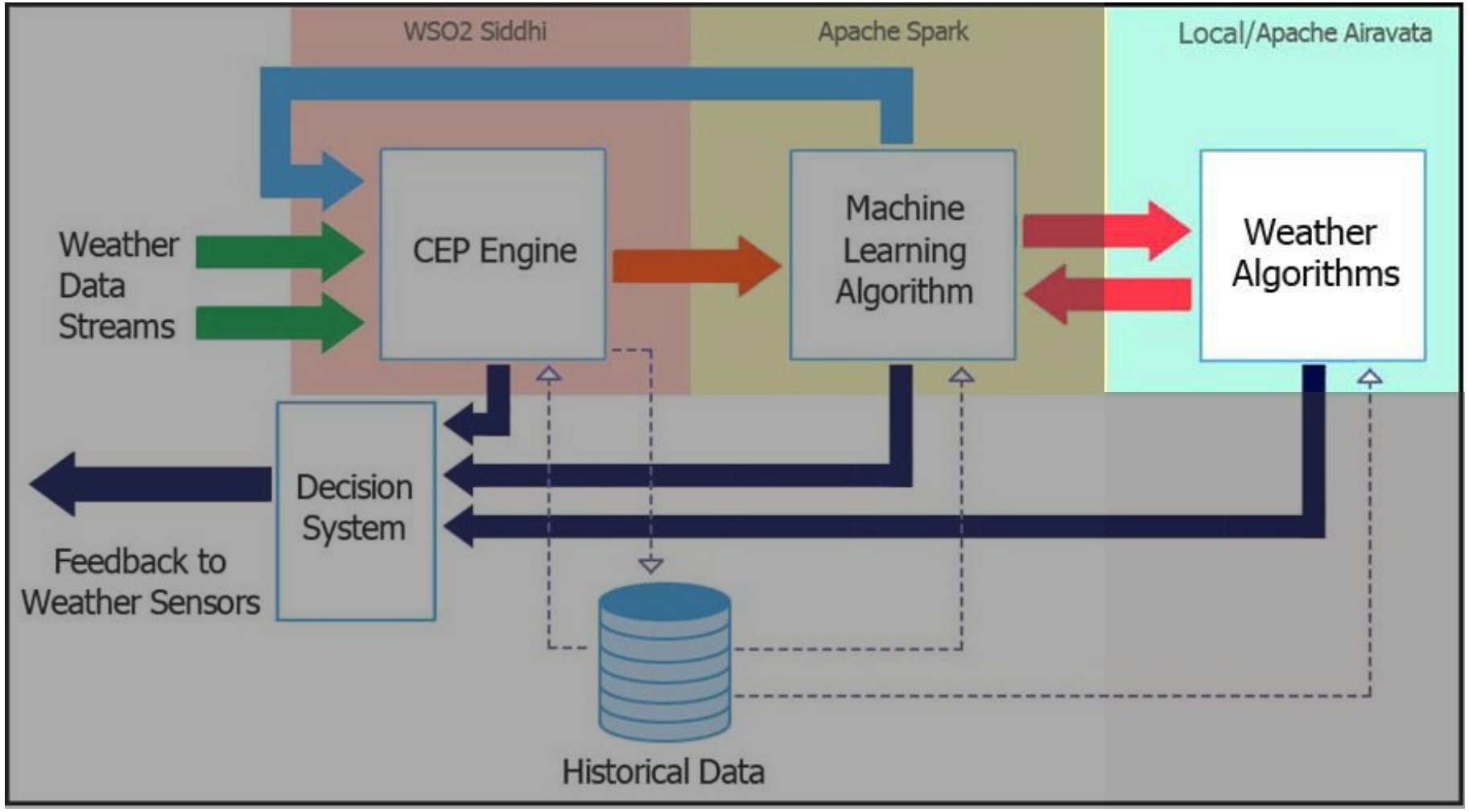

WRF Model

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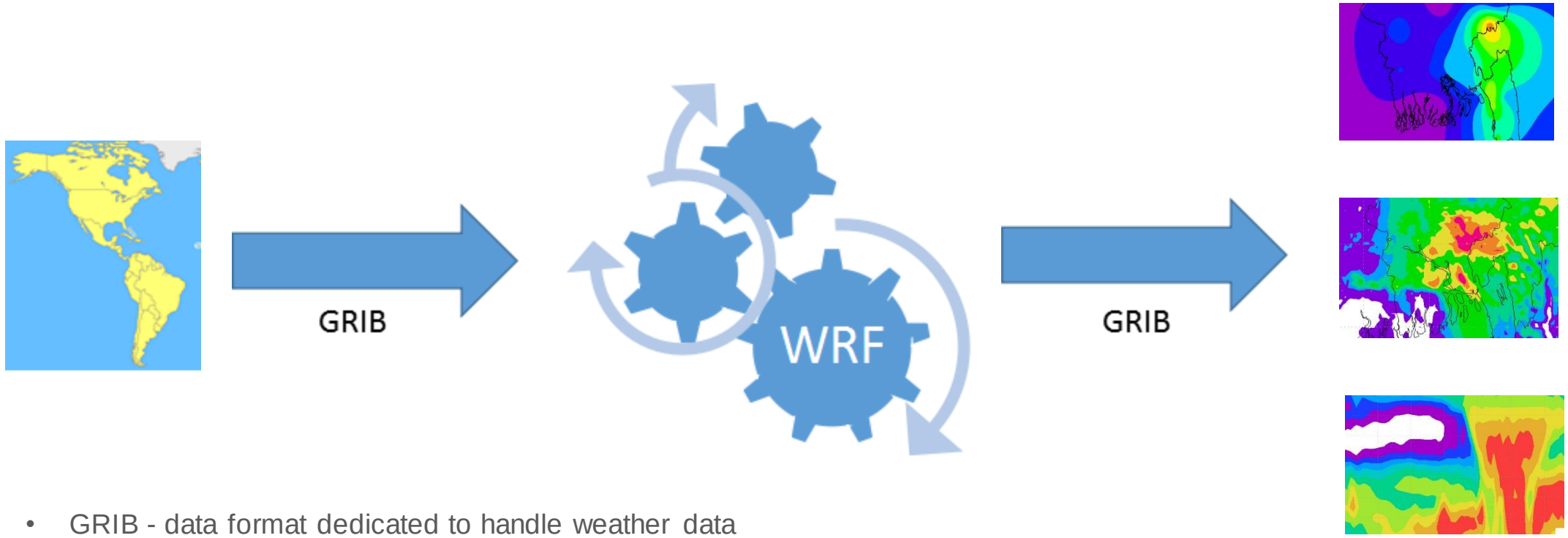

- GRIB - data format dedicated to handle weather data
- GRIB data provided to WRF model
- Output is received in GRIB/netCDF
- Post processing to get insight

WRF Model

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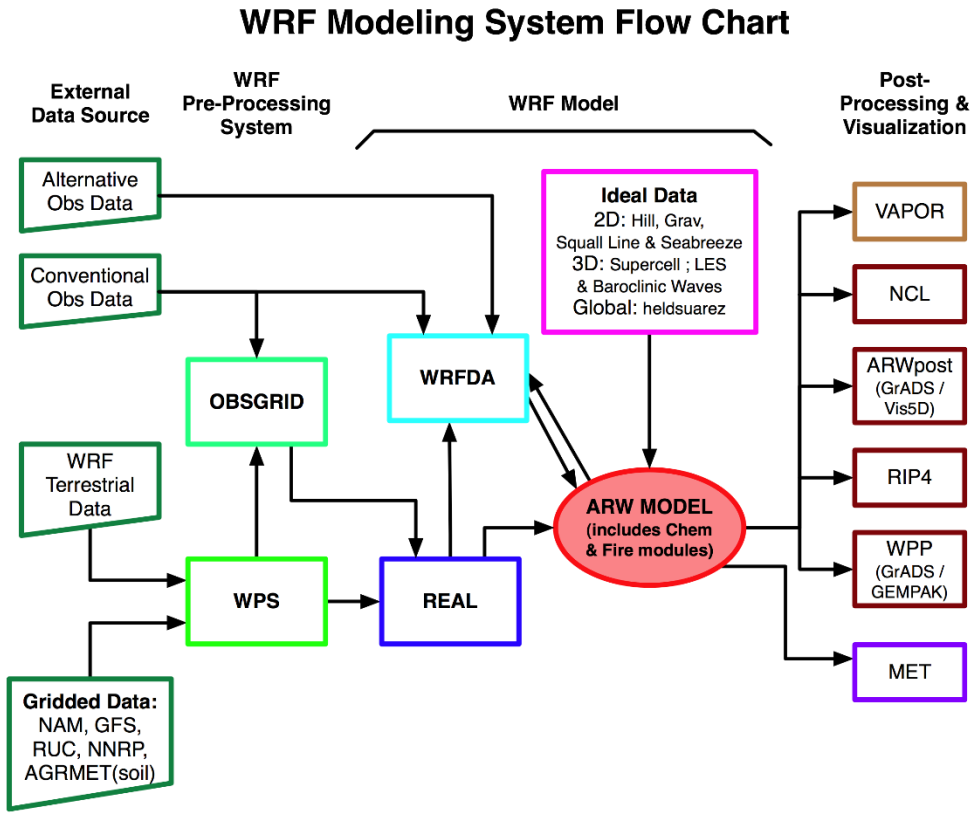

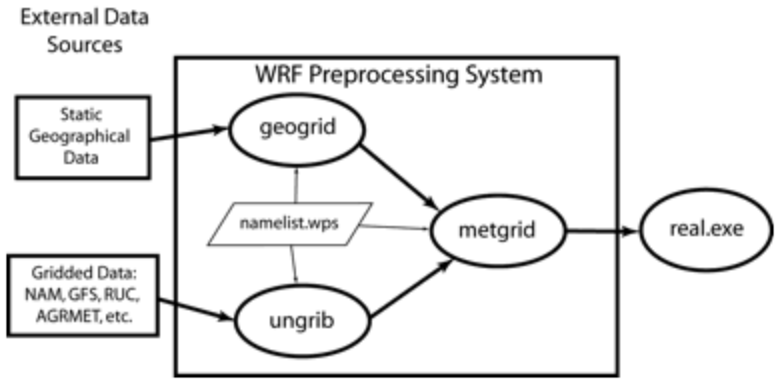

WRF Model

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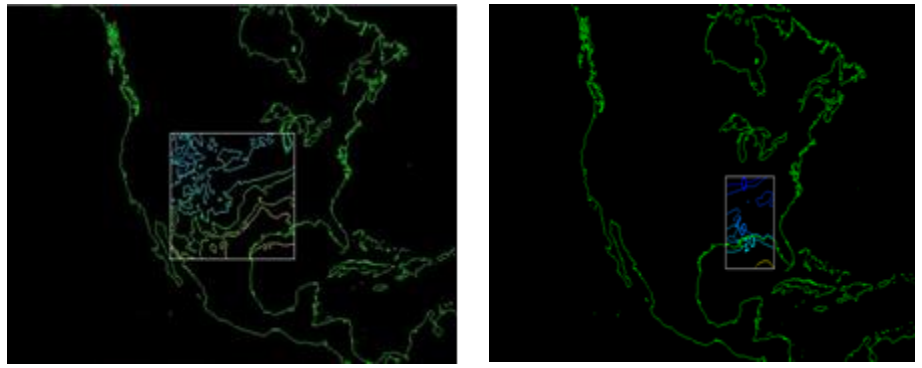
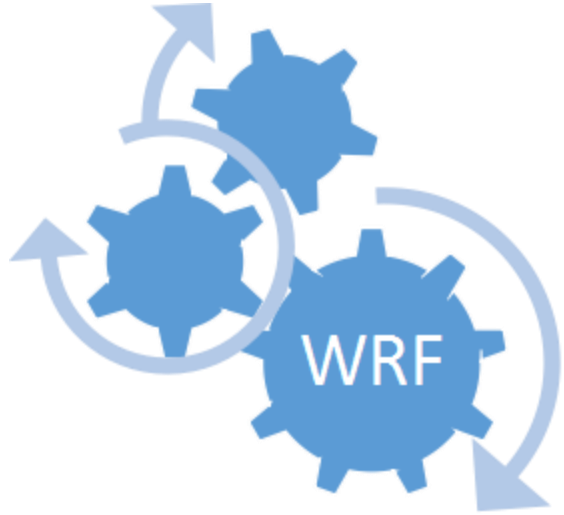
Namelist Configuration





PERFORMANCE EVALUATION

CEP Based Filtering

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3 Performance Evaluation

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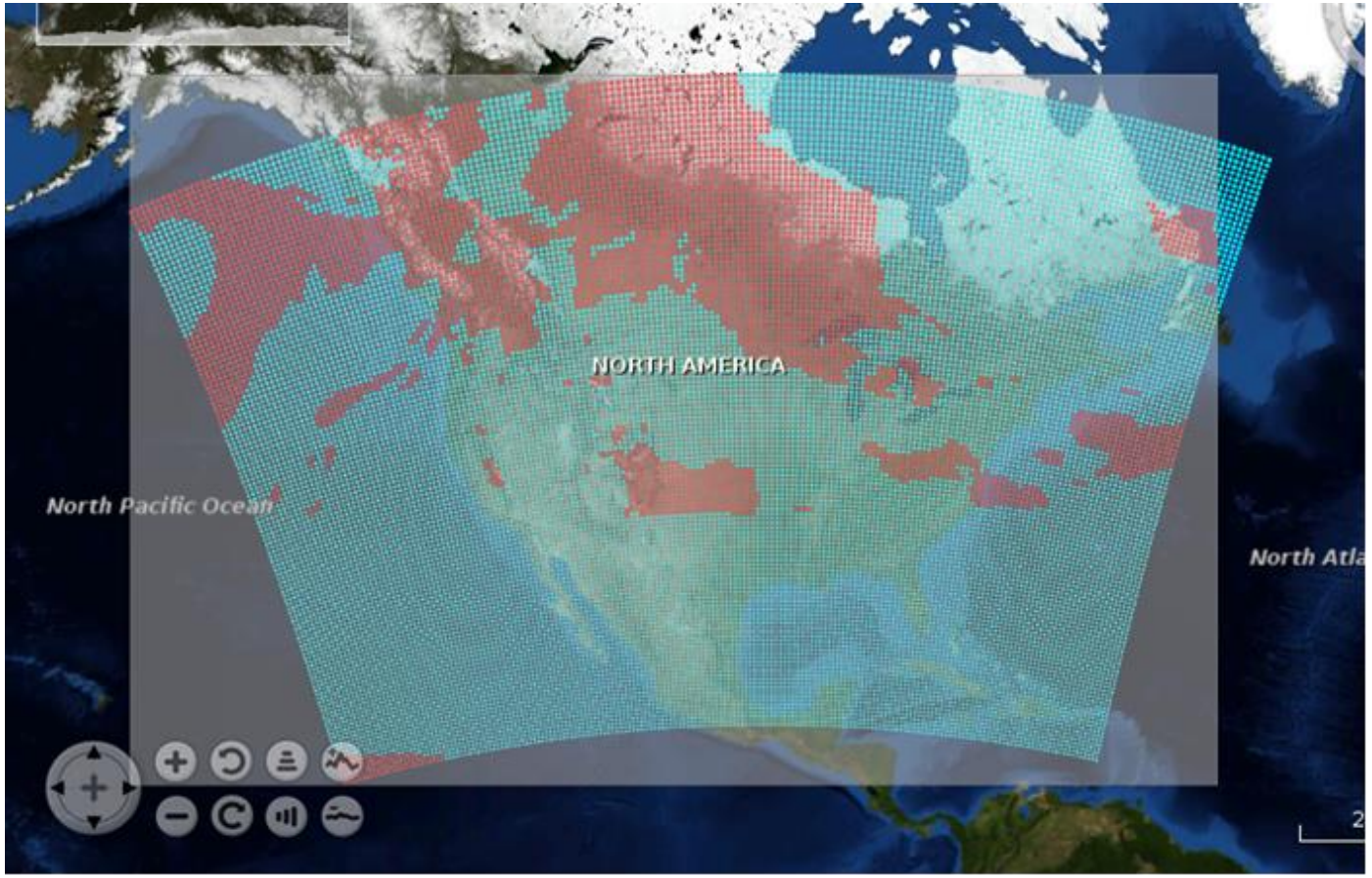
Using Thunderstorm Indices

- Best 4 layer Lifted Index
- Storm Relative Helicity
- Convective Inhibition



23866 Input Data Records
Execution Time : 15.75 seconds

ML Based Clustering

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3 Performance Evaluation

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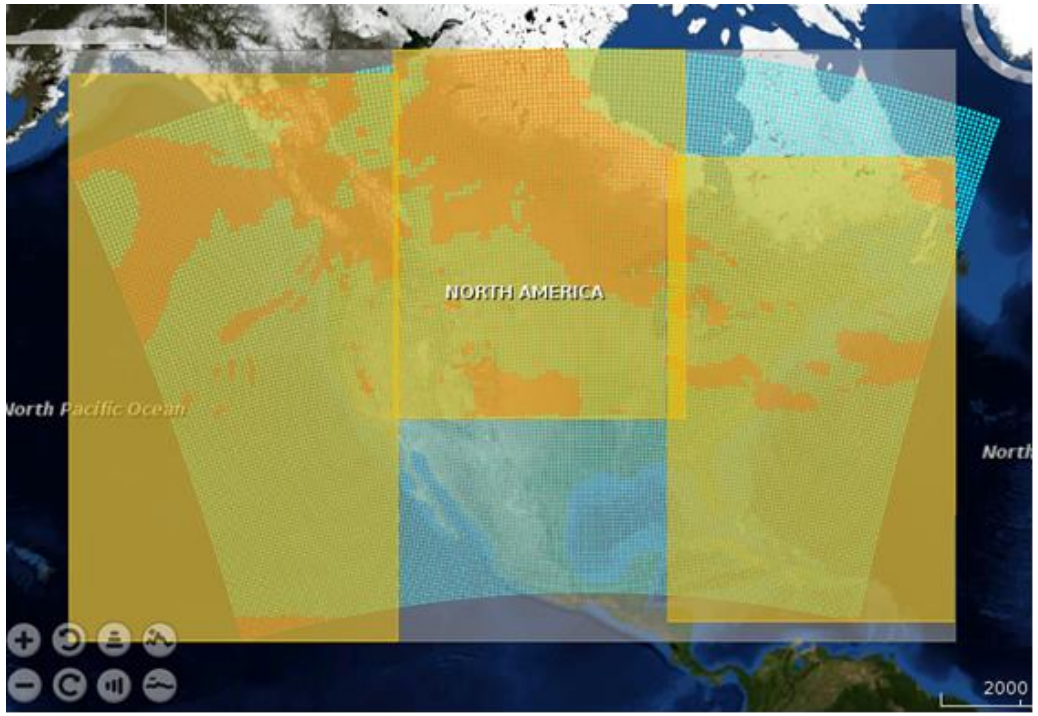
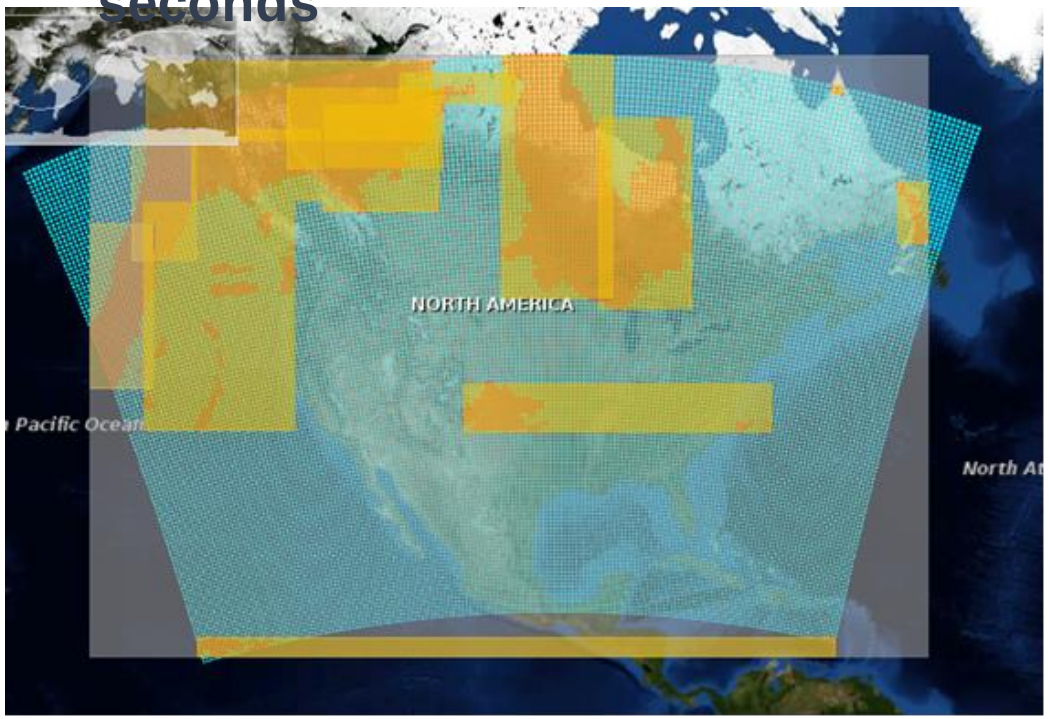
K-Means Algorithm : 19.299 seconds



GMM Algorithm : 63.063 seconds



Results Comparison

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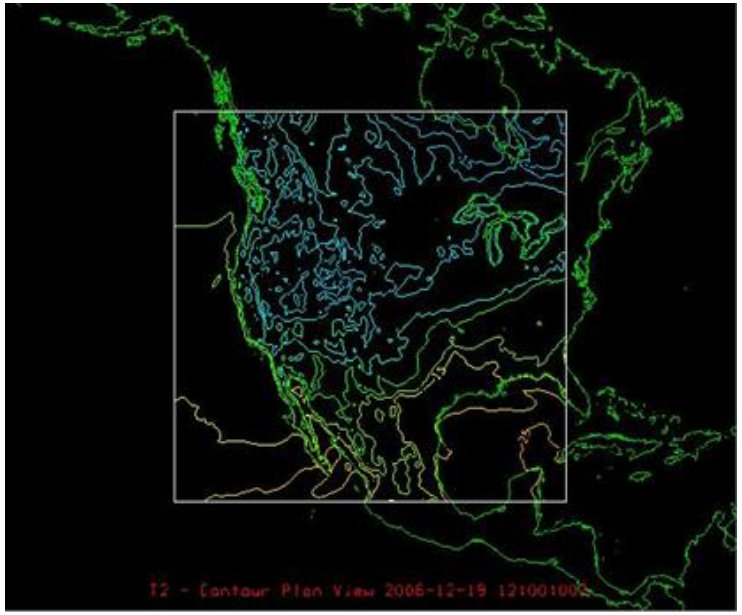
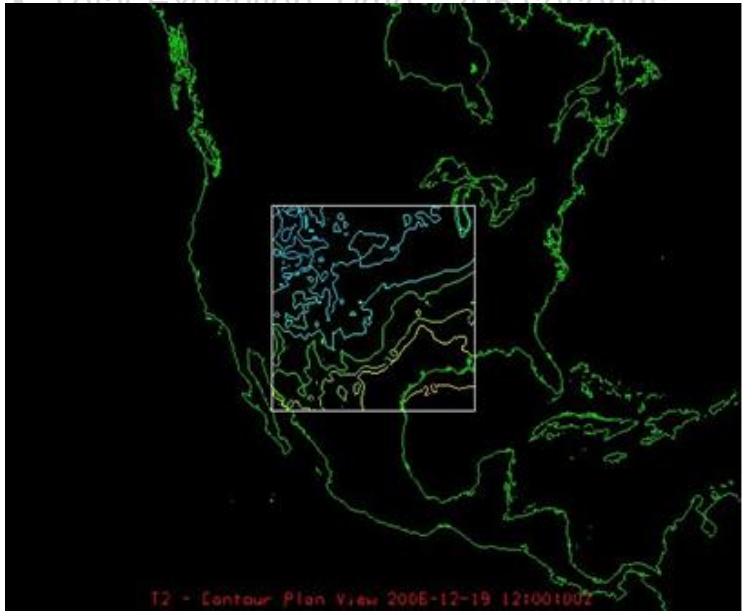
Scenario 1

- Without Preprocessing
- Total Execution Time :745 seconds



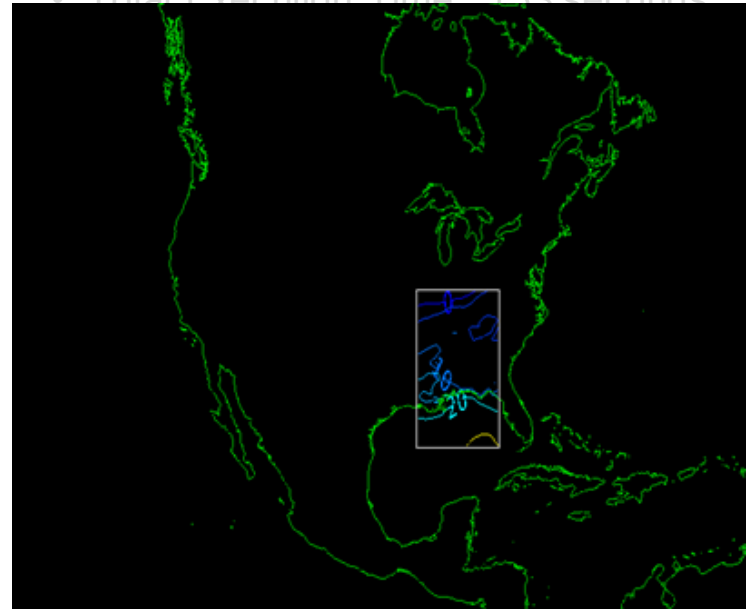
Scenario 2

- Clustering using K Means
- WRF Execution Time : 165.632 seconds
- Total Execution Time : 305 seconds



Scenario 3

- Clustering using GMM
- WRF Execution Time : 73.978 seconds
- Total Execution Time : 153 seconds



Execution Time Comparison

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3 Performance Evaluation

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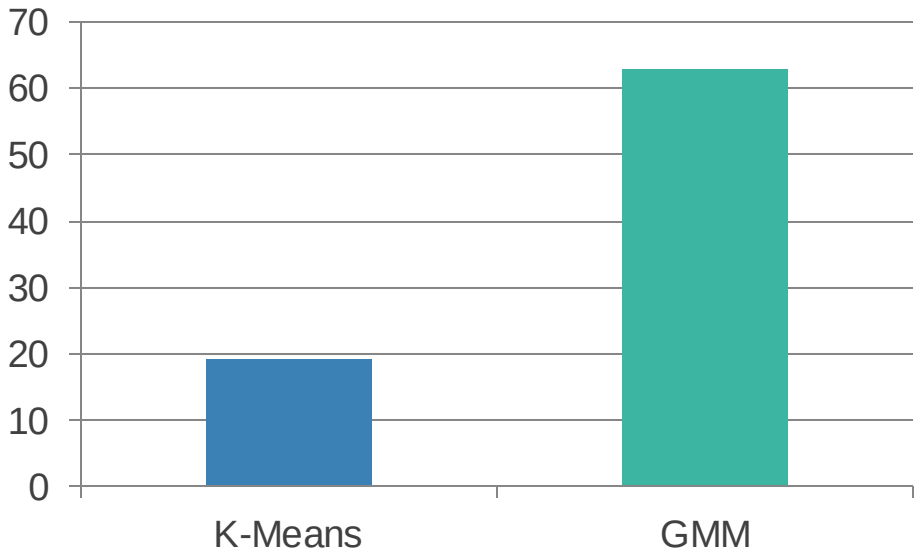
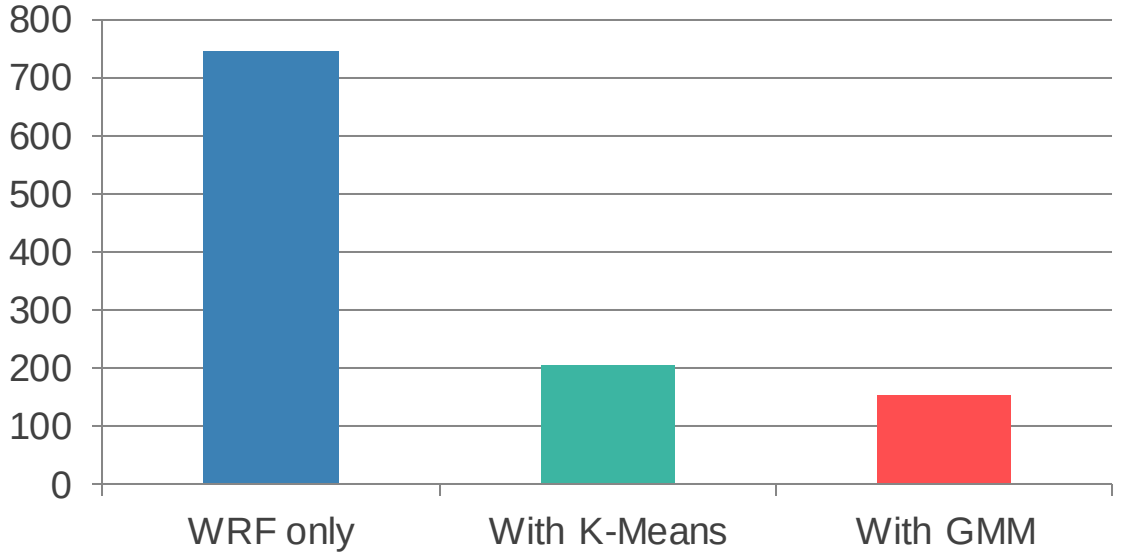


ML Algorithm Execution time (Seconds)



Total Execution Time (Seconds)

- Significant Time Gain
- GMM : Expensive Algorithm But Gives Better Performance in Clustering

FUTURE IMPROVEMENTS

Enhancements

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5 Future Improvements

- Proof of concept
- Identifies only the thunderstorm signatures
- Other weather indices should be added
- Better algorithm to find “k” value in GMM clustering algorithm
- Feeding streams of data from different weather data sources
- Adapting the input data collection resolution dynamically wrt the feedback from individual components

Conclusion

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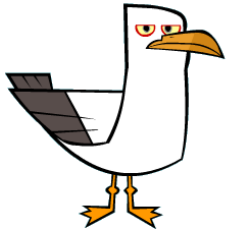
5 Future Improvements

- We have built a successful prototype of the solution concept
- Statics shows a considerable improvement of the running time of WRF module when integrated with our system
- Total running time of the forecasting procedure has reduced by 75%-85% without affecting the accuracy of the results
- The solution is feasible, cost-effective and can be further extended

THANK YOU!



chamil.11@cse.mrt.ac.lk

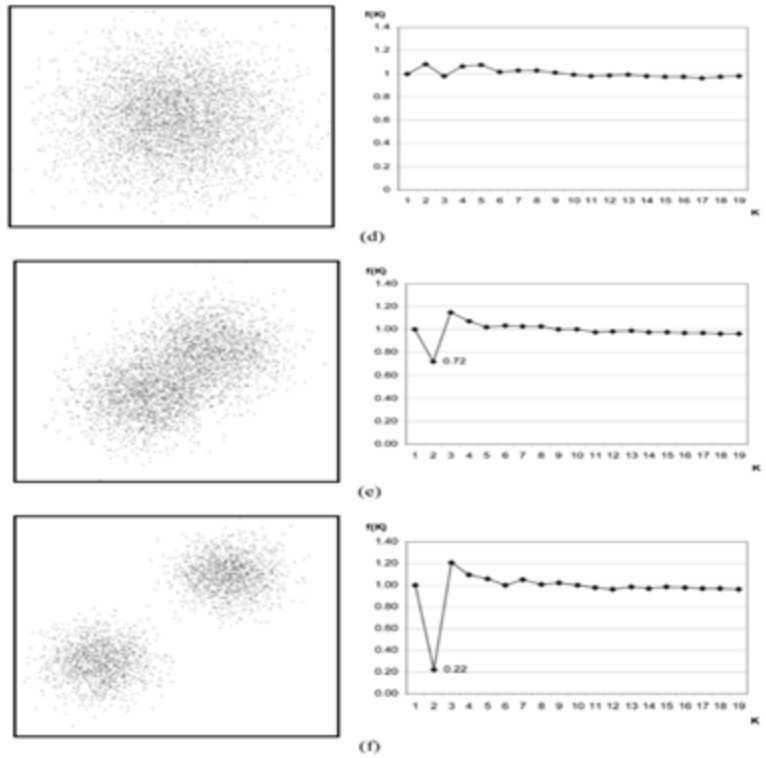
BACKUP SLIDES

ML Clustering Layer

Standard K-Means for Clusterin

- Faster compared to other clustering algorithms
- Need to specify ‘K’

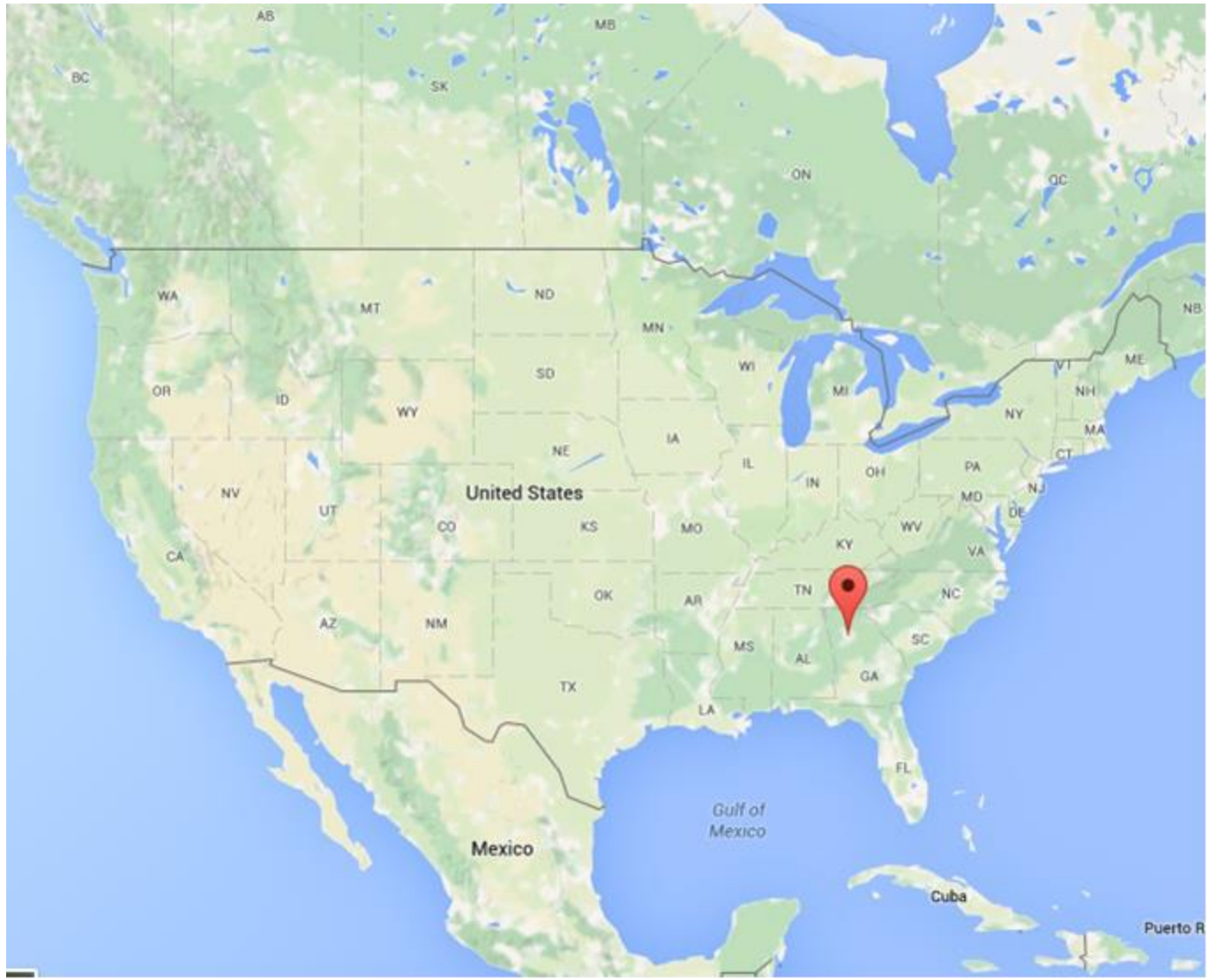
Finding the ‘K’



Solution :
Improved K-Means

Event Details

Event	**Thunderstorm Wind**
Magnitude	**50 kts.**
State	**TEXAS**
County/Area	**WISE**
WFO	**FWD**
Report Source	**Department of Highways**
NCDC Data Source	**CSV**
Begin Date	**2006-12-20 06:00:00.0 CST-6**
Begin Location	**9SSW DECATUR**
Begin Lat/Lon	**33.11/-97.54**
End Date	**2006-12-20 06:00:00.0 CST-6**
End Location	**9SSW DECATUR**
End Lat/Lon	**33.11/-97.54**
Deaths Direct/Indirect	**0/0** (fatality details below, when available...)
Injuries Direct/Indirect	**0/0**
Property Damage	**10.00K**
Crop Damage	**0.00K**
Episode Narrative	**An upper level low pressure system and associated Pacific front moved through North Texas in the early morning hours.**
Event Narrative	**A few signs were blown down along Highways 114 and 151 near the leading edge of a shallow line of thunderstorms.**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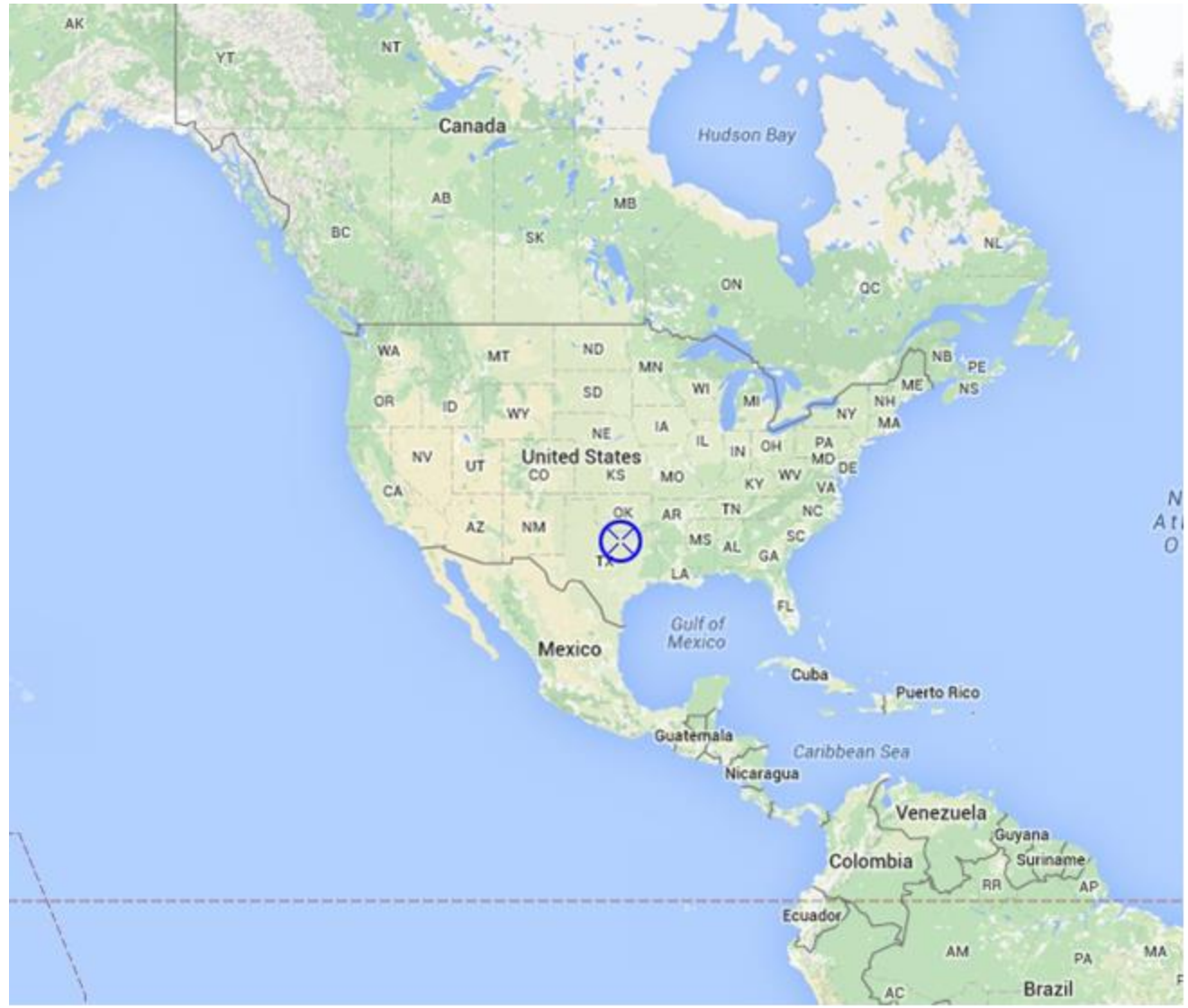
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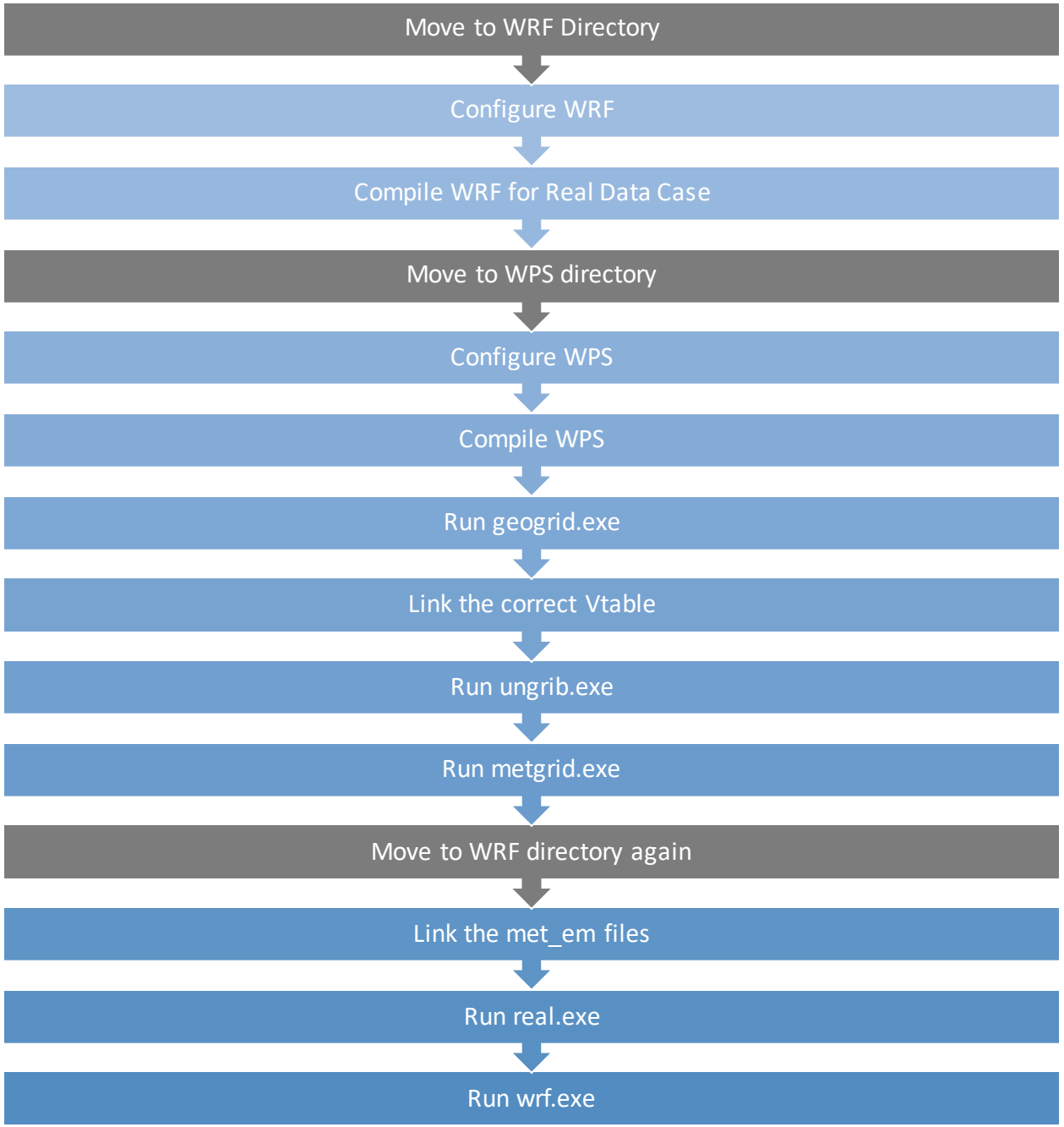
GA
TX
LA
FL
Gulf of Mexico
Mexico
Cuba
Puerto Rico
Guatemala
Caribbean Sea
Nicaragua
Venezuela
Guyana
Colombia
Suriname
RR
AP
Ecuador
AM
PA
MA
AC
Brazil

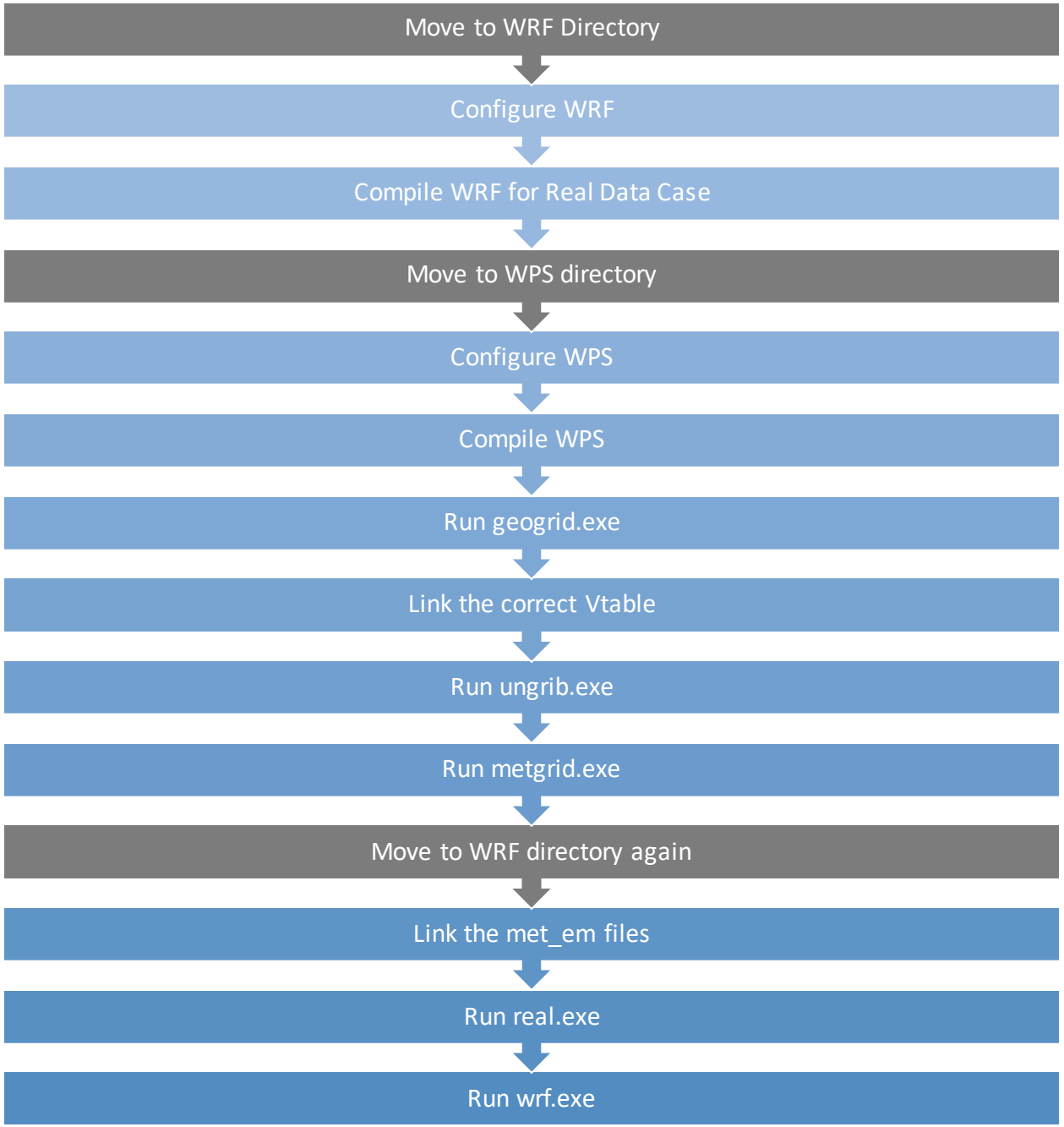
```
&share
wrf_core = 'ARW',
max_dom = 2,
start_date = '2008-03-24_12:00:00','2008-03-24_12:00:00',
end_date = '2008-03-24_18:00:00','2008-03-24_12:00:00',
interval_seconds = 21600,
io_form_geogrid = 2
/

 &geogrid
parent_id = 1, 1,
parent_grid_ratio = 1, 3,
i_parent_start = 1, 31,
```

Figure 4.18 - namelist.wps file contents

```
j_parent_start = 1, 17,
s_we = 1, 1,
e_we = 74, 112,
s_sn = 1, 1,
e_sn = 61, 97,
geog_data_res = '10m','2m',
dx = 30000,
dy = 30000,
map_proj = 'lambert',
ref_lat = 34.83,
ref_lon = -81.03,
truelat1 = 30.0,
truelat2 = 60.0,
stand_lon = -98.,
geog_data_path = '/mmm/users/wrfhelp/WPS_GEOG/'
/
&ungrib
out_format = 'WPS',
prefix = 'FILE',
/
&metgrid
fg_name = 'FILE'
io_form_metgrid = 2,
/
```


Move to WRF Directory
Configure WRF
Compile WRF for Real Data Case
Move to WPS directory
Configure WPS
Compile WPS
Run geogrid.exe
Link the correct Vtable
Run ungrib.exe
Run metgrid.exe
Move to WRF directory again
Link the met_em files
Run real.exe
Run wrf.exe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Run ungrib.exe
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Move to WRF directory again
Link the met_em files
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Run wrf.exe

What we achieved

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5 Future Improvements